South River
Conceptual Site Model
RRM 0 to 5

South River Science Team Meeting
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Conceptual Site Model (CSM)

- Representation of an environmental system
- Presents hypotheses about the most important processes that control the behavior and fate of a substance from sources to receptors
- Complexity of the CSM is determined by the complexity of the site and the complexity of the behavior of the substance of interest

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Uses of CSM - A Tool to:

- Integrate all site data and understanding of the system
- Identify critical transport and exposure pathways
- Test and refines hypotheses through site characterization and field testing to define complete pathways
- Serve as a basis for more detailed evaluation on different spatial and temporal scales
- Identify data gaps and R&D needs
- Identify potential remedial strategy options and evaluate potential effectiveness
- Update what is understood about the system after actions are implemented to reduce receptor exposure to contaminants
- Communicate the important processes of the system among:
  - Scientists
  - Stakeholders
  - Decision-makers

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South River CSM Objectives

- Identify Hg sources and pathways that are primarily responsible for elevated Hg levels in smallmouth bass in the South River
- Identify specific pathways that are feasible to interrupt to effectively reduce Hg levels in smallmouth bass

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South River CSM Study Approach

- Initial focus on aquatic environment
- Begin with baseline flow conditions, annual basis, RRM 0 to 5
    - Includes Invista outfalls
    - Includes 2 Eco Study areas
    - Mass loading to surface water increases significantly
    - Hg concentrations in biota increase significantly
    - Bank stabilization pilot part of this reach
    - Encompasses 3 NRDA reaches
- Focus on Hg sources and pathways leading to smallmouth bass as the receptor

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Update on Team Activities – Response to Expert Panel Comments

- Two-day working meeting (+ follow-up meetings)
  - Refine Quantitative CSM
  - Document lines of evidence that support the CSM (matrix)
  - Document calculation bases and data input for CSM
  - Develop bibliography for CSM
  - Begin report outline
  - Develop schematic of Hg movement in environment

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The SR CSM integrates South River data and other model results

Numerical Predictive Models
- BASS Model
- HSPF Model (TMDL)
- HEC RAS Model

Analytical Modeling
- Statistical Models
- Trophic Transfer
- Geomorphic Models
- Mass Flux Models
- HQI Loading Analysis
- Phase 1 Eco Report

Biotic Pathways

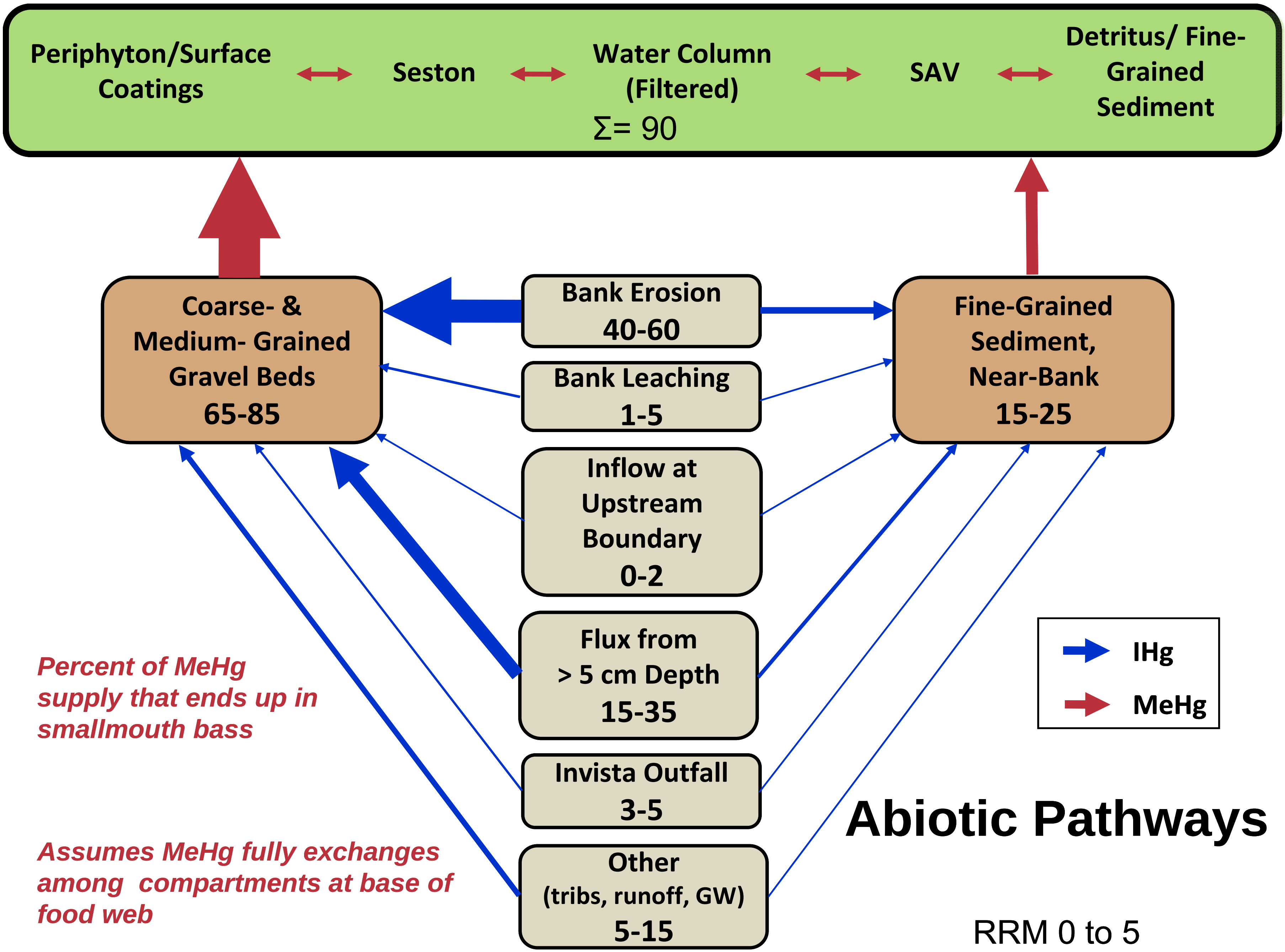
Conceptual Site Model

Abiotic Pathways

Field Data
- Eco Study Data (Phases 1&2)
- SRST Investigations
- Site Outfall Monitoring
- Bank Pilot

Lab Studies
- U. Waterloo soil and sed charac.
- U. Texas DGT
- SERC
- Battelle

Notes:
BASS - Bioaccumulation and Aquatic System Simulator



Periphyton/Surface Coatings
Seston
Water Column (Filtered)
Σ= 90
SAV
Detritus/ Fine-Grained Sediment
Coarse- & Medium- Grained Gravel Beds 65-85
Bank Erosion 40-60
Bank Leaching 1-5
Fine-Grained Sediment, Near-Bank 15-25
Inflow at Upstream Boundary 0-2
Flux from > 5 cm Depth 15-35
Invista Outfall 3-5
Other (tribs, runoff, GW) 5-15
IHg
MeHg
Percent of MeHg supply that ends up in smallmouth bass
Assumes MeHg fully exchanges among compartments at base of food web
Abiotic Pathways
RRM 0 to 5

Document Data Sources for Abiotic Pathways

Hg Sources	Data / References
Tributaries	Eco Study Data (April/May/June 2008); Calculated Daily Mercury Budget for South River (Dyer and Flanders, revised 4/2011)
Groundwater	Genicom Facility / Schifflett Farm Final Soil, Groundwater, and Surface Water assessment report, Waynesboro, VA (USEPA, 2007); Bank stabilization pilot data and monitoring report (URS, 2011); Comprehensive RFI Report Former DuPont Waynesboro Site (URS, 2009); Report on Groundwater at Basic Park (Turner & Jensen, 2006)
Floodplain Runoff	Mercury floodplain study and analysis (VA DEQ, 2008); Phase 1 Eco Study Report (URS, 2006)
Invista Plant Outfalls	Stormwater outfall monitoring data collected 2003-2006 as part of RCRA Corrective Action permit; Mercury Loading to South River from Plant Outfalls-Analysis of Base Flow and Storm Flow Data (Dyer, Nov. 2007); TMDL Development for Mercury in the South River, South Fork Shenandoah River, and Shenandoah River, Virginia (USGS, 2009)
Inflow at Upstream Boundary	Phase I & II Eco Study surface water monitoring data (URS, 2005-2010); Conceptual Site Model for Mercury in the South River, VA, (HydroQual, Inc., 2009)
Bank Erosion	Bank Erosion Estimates based on Aerial Photography Analysis, Erosion Pins and Land-based LiDAR Surveys (Pizzuto et al.,2006-2011)
Bank Leaching	Sediment-column leaching data and flux estimates for bank soils (University of Waterloo, 2010-2011)
Flux from > 5 cm Depth	Benthic flux chamber data (Landis, 2006-2008), Mass Transfer analytical models to predict flux based on pore water data (Dyer and Landis, 2009-2011)

Example: Key Observations / Assumptions for Abiotic Pathways in the CSM*

- Key Assumption: Inorganic Hg sources in the outfall, tributaries, in bank soils, GW and others are assumed to be equally available for methylation
- Key Observation: Direct loading of MeHg from floodplain soil is small compared to MeHg production within the wetted perimeter of the river
- Key Assumption: MeHg production in the river is based on bed area and measured pore water concentrations (bed area x pore water concentration)
  - Coarse- and medium-grained gravel beds comprise ~85% of river bed
  - Median FIHg Pore Water concentrations for sand/silt substrates are 1X-4X median pore water concentrations for cobble/gravel substrates

*See Matrix for more detail

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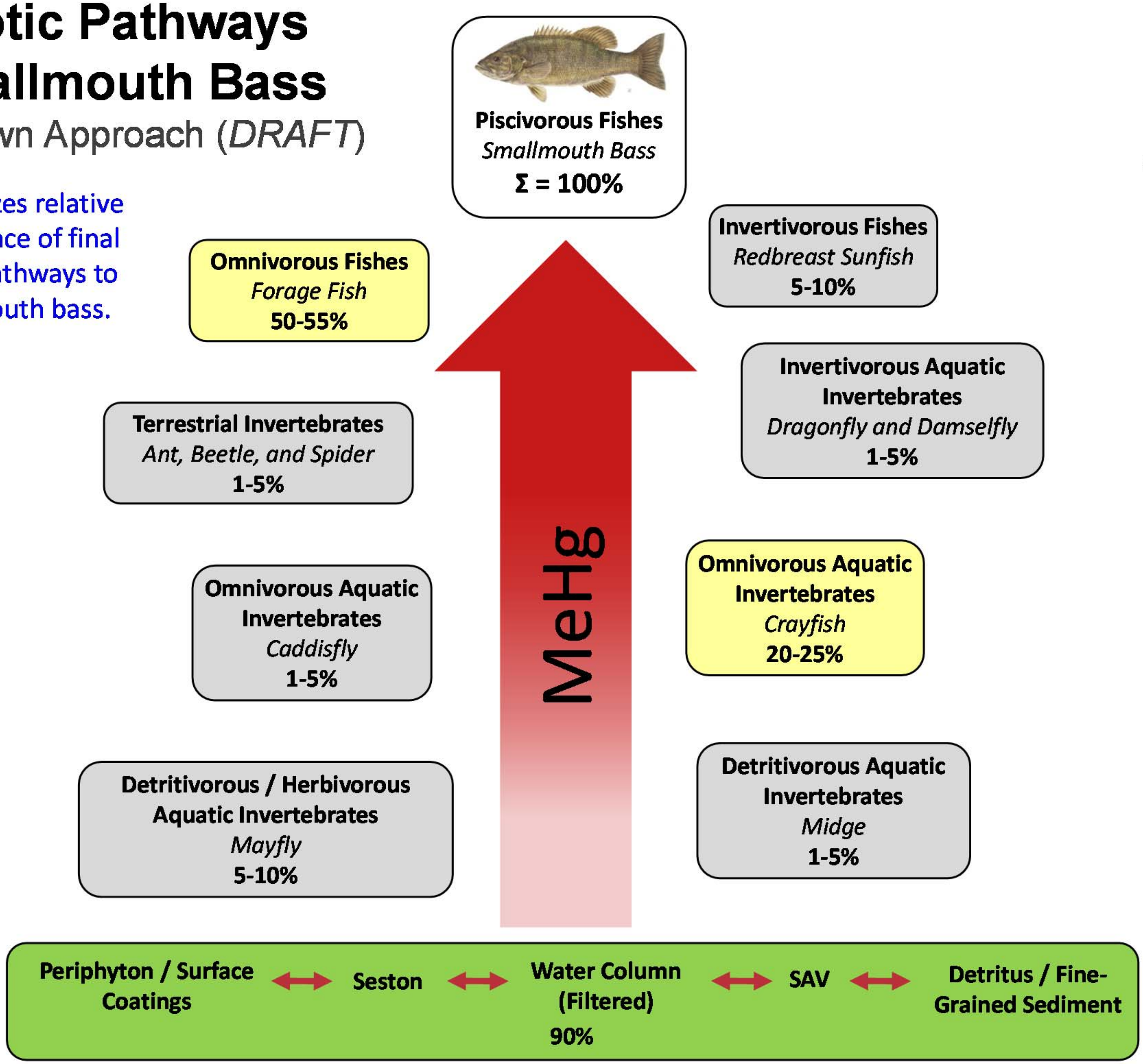
Biotic Pathways Smallmouth Bass

Top Down Approach (*DRAFT*)

Emphasizes relative importance of final MeHg pathways to smallmouth bass.



Data Sources for Biotic Pathways

Biotic Pathway Components	Data / References
MeHg in Biological / Physical Media	• South River Science Team database containing MeHg information from various programs
MeHg Uptake Pathways	• Phase II Ecological Study - BASS model outputs for smallmouth bass, redbreast sunfish, and common shiner • Phase II Ecological Study - *In situ* Hg uptake study for mayfly nymph and crayfish
Dietary Composition	• Phase II Ecological Study - Fish stomach content analyses for smallmouth bass, redbreast sunfish, and common shiner • Snyder and Hendricks (1995) • Merritt et al. (2008)
Assimilation Efficiency	• Wiley and Wike (1986) • Shuter and Post (1990) • Headon et al. (1996) • Trebitz (1997) • Duffy (1998) • Karimi et al. (2007)

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Example: Approach / Key Assumptions for Biotic Pathways in the CSM*

- Key Approach: Top down approach emphasizes relative importance of final MeHg pathways to smallmouth bass; while bottom up approach emphasizes relative importance of initial MeHg pathways from basal resources to aquatic consumers.
  - Multiple direct and indirect links between various trophic compartments; must consider both approaches
- Key Assumption: Differences between dietary and aqueous treatments observed during *in situ* uptake experiment are representative of true conditions.
  - Mayfly nymph uptake was approximately 55% and 45% for dietary and aqueous treatments, respectively
  - Crayfish uptake was approximately 66% and 34% for dietary and aqueous treatments, respectively

*See Matrix for more detail

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Next Steps

- Develop Schematic "Mercury Movement through the South River"
- Refine CSM by incorporating results of 2011 efforts
  - Hg loading from eroding banks
  - Substrate mapping
- Develop Aquatic CSM under Storm conditions
- Develop Aquatic CSM for RRM 5 to 11
- Develop Floodplain CSM

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Implications of Storm Event on Abiotic Portion of CSM

- **Key issue is the potential for a major storm to mobilize Hg and induce a newly contaminated state**
  - A storm may mobilize previously unavailable Hg via
    - redistribution of river bed sediment
    - loading of floodplain Hg to river
    - increased riverbank erosion and collapse
  - Above may be partially offset by introduction of clean sediment from upstream and reduced erosion of contaminated soil from stabilized river banks
- **Floodplain runoff contribution likely to increase**
- **Need to consider impact of wet-dry cycling on methylation in banks and on floodplain**

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Implications of Storm Event on Biotic Portion of CSM

- Wet-dry cycling and inundation-induced methylation impact on terrestrial biota
- Potential change in aquatic invertebrate biomass and community structure; though evidence that effects are short-term in duration (ref. Hendricks et al. 1995)
  - shift in fish food habits; subsequent bioenergetics & mercury uptake
  - change in mercury flux to terrestrial food web
- Change in mercury bioavailability for aquatic invertebrate uptake
  - change in mercury uptake by fish
  - change in mercury flux to terrestrial food web
- Effect on fish reproduction
  - shift in fish food habits; subsequent bioenergetics & mercury uptake

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Reporting for the CSM

- Executive Summary (10 to 20 pp.)
- Figure 1 Abiotic Pathways
- Figure 2 Biotic Pathways
- Figure 3 Schematic of Mercury Movement in the South River
  - Abiotic CSM Lines of Evidence and Supporting Documentation
  - Biotic CSM (BASS Model) Supporting information
  - Bibliography
  - Summary of Statistical Modeling Efforts and Major Conclusions
  - Mercury flux and water budget calculations
  - Previous SR Conceptual Models

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